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TEXTURE AND COLOUR CHANGES IN *Penaeus vannamei* AFTER COATINGS WITH *Piper betle* (L) LEAVES EXTRACT

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Abstract: *Penaeus vannamei* is an important aquaculture product heavily exported to countries such as Europe and China due to its high consumer demand. However, commercialisation of the product involves various levels of cold chain and time to reach consumers which can lead to rapid deterioration. The study aims to evaluate the texture and colour of *P. vannamei* after being coated with 0.5, 1.0 and 2.0% betel leaf extract for 16 days of chilled storage. *P. vannamei* was found to have slightly random insignificant changes in texture. However, the colour changes were slowly decreased especially in *P. vannamei* coated with 2.0% betel leaves extract and supported by sensory evaluation for consumer acceptance. *P. vannamei* coated with 2.0% betel leaves extract resulted in a significantly lower ($p < 0.05$) hardness (20646.11 ± 480.10 N) compared to others on the initial day and showed a slightly decreasing trend during storage but not significantly ($p > 0.05$). After 12 days of chilled storage, *P. vannamei* coated with 2.0% betel leaf extract showed a significant increased ($p < 0.05$) in springiness from 0.53 ± 0.15% at the initial day to 0.63 ± 0.06% at the end of storage day, indicating a firmer texture. *P. vannamei* coated with 2.0% betel leaves extract had the highest cohesiveness (0.35 ± 0.05%) and resilience (0.58 ± 0.06) value on the initial day but not significantly different ($p > 0.05$). However, over time, cohesiveness and resilience values showed a decreasing trend, indicating that the shrimp became less cohesive and resilient with prolonged storage. The colour of the *P. vannamei* coated with 2.0% betel leaf extract recorded a lightness L* value of 29.23 ± 0.14; redness a* value of 0.37 ± 0.25; and blueness b* value of 5.12 ± 0.37 and significantly different ($p < 0.05$) compared to *P. vannamei* coated with 0.5%, and 1.0% betel leaves extract and 1.25% SMS throughout 16 days of chilled storage. The organoleptic test showed that *P. vannamei* coated with 2.0% betel leaf extract were highly accepted by consumers. Therefore, coating *P. vannamei* with a 2.0% concentration of betel leaf extract promises a significantly improved quality of *P. vannamei* at prolonged storage.

Keywords: Whiteleg shrimp, betel leaves, quality, sensory analysis.

Introduction

Penaeus vannamei or, commonly known as whiteleg shrimp, is an important food source for humans, as it is rich in nutrients and contains polyunsaturated fatty acids. However, *P. vannamei* is easily perishable and has a limited shelf-life which depends on its pre-treatment, conditions, and duration of storage (Sae-Leaw & Benjakul, 2019). The poor appearance of *P. vannamei* can reduce its market value and lead to consumer rejection, resulting in economic loss (Gonçalves & de Oliveira, 2016). Edible coating is a promising and emerging technique in maintaining the quality of *P. vannamei*, especially in terms of texture, colour, and shelf-life extension.

A previous study conducted by Bao (2014) clearly demonstrated that the extract derived from straw mushrooms is a positive source of natural antioxidants, which can be utilised to prevent melanosis in shrimp during iced storage.

Meanwhile, the extraction of moringa leaves has also demonstrated its antioxidant properties and its ability to slow down the melanosis process in shrimp (Karim *et al*., 2018). Edible coating provides various benefits, such as delaying lipid oxidation, preserving protein functionality, reducing off-odours, discolouration, and delaying spoilage (Khaledian *et al*., 2021). Additionally, it can prolong the product freshness by delaying bacteria growth, reducing moisture loss, and acting as an antioxidant and antibacterial agent (Kumari & Thakur, 2020). Edible coating substitutes the natural layers at the product surface to prevent solute movements out of the shrimp, gas aroma and moisture losses while allowing for a controlled exchange of important gases, such as oxygen, carbon dioxide and ethylene, which are involved in food respiration (Dehghani *et al*., 2018).

In order to control discolouration and lipid oxidation in fish meat and other crustaceans' various studies related to the use of antioxidants have been conducted and widely used in the market (Encarnacion *et al.*, 2012). Antioxidants, or inhibitors of oxidation, are compounds which retard or prevent oxidation and generally prolong the life of the oxidisable matter (Chirag *et al*., 2013). Betel leaf is one of the natural herbs that comes from the betel plant, an evergreen climber that is a good source of antioxidants and antimicrobials (Sarma *et al*., 2018). The use of natural additives is expected to replace synthetic materials, such as sodium metabisulphite (SMS), which can have many negative effects on consumers (Naureen *et al*., 2021). SMS is the cheapest, easiest, and most effective method available today to preserve shrimp. It is also considered an antimicrobial food additive (Omar, 1998).

Therefore, the objective of this study is to determine the effectiveness of betel leaf extract on the texture and colour changes of *P. vannamei* during 16 days of chilled storage (4°C) and to evaluate consumer acceptance of the product. This bio-preservation technique may be introduced as a new natural alternative to maintain the quality and safety of *P. vannamei.*

Materials and Methods

Piper Betle Sample Collection and Extract Preparation

Approximately 2.0 ± 0.1 kg of matured *Piper betle* leaves freshly collected from Pagoh, Johor, were used in the experiment. The mature leaves are commonly larger, darker green in colour, have a more distinct flavour and aroma, and usually with an estimated age of six months. The betel leaves were dried in the shade at room temperature for seven days, with an average temperature of 29 ± 0.1°C. The leaves were pulverised into powder by using a Waring blender (Waring Commercial, Malaysia). Sample extractions were performed according to the method described by Ibrahim *et al*. (2022), with some modifications. Approximately 30 ± 0.1 g of betel powder was mixed with 200 ml solvent (6:4) methanol-distilled water. The mixture was shaken at room temperature for 24 h using a Stuart Orbital Shaker (Fisher Scientific, Malaysia), followed by filtration with Whatman filter paper number 1. The mixture was dried using a rotary evaporator R-210 (Buchi, Switzerland) to remove excess solvent. The extract was kept in a container at room temperature prior to further analysis.

Penaeus Vannamei Preparation

Fresh *P. vannamei* of approximately 15 ± 0.5 g was immersed at different concentrations of 0.5, 1.0 and 2.0 % betel leaves extract and 1.25% SMS treatment for 20 minutes, respectively. The controls were left untreated. All samples were stored at chilled storage at 4°C for 16 days. All analysis was carried out in triplicate at intervals of 4 days during 16 days of storage.

Texture Analysis of Panaeus vannamei

Texture profile analysis of *P. vannamei* including hardness, springiness, cohesiveness, and resilience, was done by using TA.XT Plus Texture Analyser (Stable Micro System, United Kingdom). The instrument was set up to a pre-test speed of 1.0 mm s^{-1}, test speed of 0.10 mm s^{-1}, post-test speed of 1.0 mm s^{-1}, and trigger force of 5.0 g. The samples were compressed to 50% of their height using an aluminium cylinder probe of 4 mm diameter and the test speed was at 1 mm s^{-1}.

Colour Analysis of Panaeus vannamei

A CR-400 colourimeter (Konica Minolta, Japan) was used to determine the colour changes in *P. vannamei* throughout 16 days of chilled storage. The readings were recorded in a CIE L*, a*, b* colour space, where L* represents the brightness from black (0) to white (100), a* represents from green to red, and b* represents from blue colour to yellow. The instrument is calibrated using a white standard plate. The readings were taken in triplicate at intervals of 4 days during 16 days of chilled storage.

Sensory Analysis of Panaeus vannamei

Sensory analysis was performed by the method of Balfour *et al*. (2014) with some modifications. This sensory test was included to measure consumer acceptance of obvious changes in the shrimp by experienced panellists. A total of 20 panellists were involved in this experiment with experience in the field of shrimp processing between 2 to 10 years at Greater Asia Agro Bhd. The panellists performed the sensory evaluations at daily intervals during the 16 days of chilled storage. The observed criteria involve colour, texture, and odour.

Statistical Analysis

All analysis was performed in triplicate (*n* = 3) and the data were represented as mean ± standard deviation. The collected data was tabulated and analysed using IBM SPSS Statistic Version 20 software (IBM Corporation, New York). The data was subjected to two-way ANOVA with Ryan, Einot, Gabriel, Welsh Range Q (REGWQ) post hoc test. In all analyses by ANOVA, the residuals were inspected for normality and homogeneity of variance across the treatments. Different superscripts (A, B, C, D, E) were used to indicate significant different ($p < 0.05$) between storage days. Meanwhile, different superscripts (a, b, c) were used to indicate significant different ($p < 0.05$) between treatments.

Table 1: Grading description scheme on the quality of whole shrimp Balfour *et al*., (2014)

		Criteria		
		Colour	**Texture**	**Odour**
Grading	**Excellent**	Body has dark red to bright pink	Firm, body has a cleaned defined shape	Strong seaweedy, marine odour
	Good	Body has a natural light pink to white	The flesh has slight firmness; the body still has a defined shape	Weak characteristic shrimp odour
	Moderate	Naturally light pink with grey-greenish or yellowish discoloration	Flesh soft to the touch, may easily be pushed by a finger	Marine odours are diminishing, weak fishy odours, even slight ammonia
	Borderline	Naturally pink with grey-greenish or yellowish discoloration	Flesh may be easily pushed by a finger	Weak ammonia odour
	Unfit	Naturally pink with grey-greenish or yellowish discoloration. Lack defined colour	Flesh soft and pliable	Ammonia odour

Results and Discussion

Texture Analysis of Panaeus vannamei

P. vannamei coated with 1.25% SMS was recorded as the lowest hardness value compared to others on the initial day. Meanwhile, the controls showed the highest hardness value compared to others but were not significantly ($p > 0.05$) different. Hardness value showed a fluctuating trend throughout the 16 days of storage in most samples, except for *P. vannamei* coated with 1.0% betel leaves extract, where it was uniformly degrading throughout the storage days. However, the hardness results of all samples showed no significant difference ($p > 0.05$) to one another during the 16 days of storage.

The changes in *P. vannamei* hardness are due to the proteolysis in the flesh, which is caused by endogenous and microbial enzymes (Jeyakumari *et al.*, 2019). The effect observed on the *P. vannamei* was minimal based on the results. A higher hardness value of *P. vannamei* indicates a low quality, good quality *P. vannamei* meat should have a firm texture and be consistent in appearance and should not be mushy or overly soft (Kim *et al.*, 2020).

On the initial day, *P. vannamei* coated with 2.0% betel leaf extract showed a lower springiness value compared to *P. vannamei* coated with 0.5% betel leaf extract (Table 3). Interestingly, *P. vannamei* coated with 2.0%

Table 2: Hardness of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control (N)	0.50% Betel Leaves Extract (N)	1% betel Leaves Extract (N)	2% betel Leaves Extract (N)	1.25% SMS (N)
0	25578.78 ± 4420.80^{Aa}	22646.10 ± 3396.52^{Aa}	22080.97 ± 1233.26^{Aa}	20646.11 ± 480.10^{Ab}	20093.15 ± 1235.35^{Aa}
4	23045.16 ± 938.38^{Aa}	19394.65 ± 852.80^{Aa}	21750.53 ± 1920.50^{Aa}	17795.19 ± 2168.88^{Ba}	23369.41 ± 1302.94^{Aa}
8	9398.54 ± 2207.53^{Aa}	21214.23 ± 2853.49^{Ab}	20605.47 ± 502.44^{Ab}	20397.18 ± 109.47^{Ab}	22060.89 ± 3615.23^{Bb}
12	23063.41 ± 1735.53^{Aa}	20477.28 ± 4189.14^{Aa}	19016.90 ± 1135.33^{Aa}	18776.97 ± 1039.44^{ABa}	17947.75 ± 2482.63^{Aa}
16	19263.99 ± 5077.74^{Aa}	21097.99 ± 5832.10^{Aa}	18632.53 ± 7457.90^{Aa}	17013.86 ± 5111.05^{Aa}	22067.91 ± 598.73^{Aa}

Note: Capital letters indicate significant differences between different storage days for the same treatment and small letters indicate significantly different treatments for the same storage day.

Table 3: Springiness of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control (N)	0.50% Betel Leaves Extract (N)	1% Betel Leaves Extract (N)	2% Betel Leaves Extract (N)	1.25% SMS (N)
0	0.72 ± 0.16^{Aab}	0.93 ± 0.03^{Ab}	0.81 ± 0.20^{Aab}	0.53 ± 0.15^{Aa}	0.64 ± 0.20^{ABab}
4	0.74 ± 0.19^{Aa}	0.88 ± 0.10^{Aa}	0.85 ± 0.05^{Aa}	0.70 ± 0.12^{ABa}	0.87 ± 0.02^{Ba}
8	0.64 ± 0.25^{Ba}	0.66 ± 0.27^{Aab}	0.65 ± 0.06^{Ab}	0.65 ± 0.21^{Bab}	0.70 ± 0.14^{ABab}
12	0.65 ± 0.22^{Aab}	0.70 ± 0.15^{Aab}	0.68 ± 0.05^{Aab}	0.63 ± 0.06^{Bb}	0.54 ± 0.30^{Aa}
16	0.77 ± 0.15^{Aa}	0.77 ± 0.25^{Aa}	0.72 ± 0.24^{Aa}	0.64 ± 0.23^{ABa}	0.74 ± 0.12^{ABa}

Note: Capital letters indicate significant differences between different storage days at the same treatment and small letters indicate significantly different treatments at the same storage day.

betel leaves extract showed an increasing trend from 0.53 ± 0.15% at 0 day to 0.63 ± 0.06 % at 12th days of storage. Meanwhile, *P. vannamei* coated with 1.25% SMS showed a lower value compared to the control, with no significant difference (P > 0.05) on the 16 days of the experiment. The springiness of the *P. vannamei* provides a sensation of comfort when chewed and provides satisfaction for its connoisseurs (Salasiah & Jirarat, 2018). If the texture of the *P. vannamei* is too soft or easily crumbled, the food can taste unpleasant and has no satisfying taste. On the other hand, if the texture of the *P. vannamei* is too hard, the food can be difficult to chew and uncomfortable in the mouth.

The cohesiveness value of *P. vannamei* coated with 2.0% betel leaf extract showed the highest value but was not significantly different (p < 0.05) compared to other treatments at the initial days. Coatings with 0.5 and 1.0% betel leaf extract showed no significant effects (p > 0.05) on the cohesiveness value of *P. vannamei* during 16 days of storage (Table 4). Meanwhile, the cohesiveness value of *P. vannamei* coated with 1.25% SMS showed a significant increased (p < 0.05) value after being stored for 12 days. Cohesiveness texture refers to the ability of *P. vannamei* texture to maintain its integrity and not fall apart when bitten, as well as provide a special taste and texture sensation when chewed. The consumer indicates that *P. vannamei* is fresh and highly acceptable to consume. The higher the cohesiveness coefficient, the better able the *P. vannamei* texture is to maintain the integrity and roundness of the texture during chewing or processing in the mouth.

The resilience value was significantly higher (p < 0.05) in *P. vannamei* coated with 2.0% betel leaf extract compared to other treatments on the initial day (Table 5). However,

Table 4: Cohesiveness of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control (N)	0.50% Betel Leaves Extract (N)	1% Betel Leaves Extract (N)	2% Betel Leaves Extract (N)	1.25% SMS (N)
0	0.24 ± 0.04 Aa	0.24 ± 0.01 Aa	0.25 ± 0.04 Aa	0.35 ± 0.05 Ab	0.21 ± 0.07 Aa
4	0.19 ± 0.02 Aa	0.23 ± 0.01 Aa	0.23 ± 0.04 Aa	0.25 ± 0.04 Ba	0.26 ± 0.00 ABa
8	0.23 ± 0.04 B	0.25 ± 0.03 Aab	0.26 ± 0.02 Ab	0.27 ± 0.02 Bab	0.28 ± 0.06 ABab
12	0.24 ± 0.05 ABab	0.24 ± 0.06 Aab	0.24 ± 0.03 Aab	0.25 ± 0.04 Ba	0.32 ± 0.10 Bb
16	0.24 ± 0.04 ABa	0.25 ± 0.05 Aa	0.28 ± 0.07 Aa	0.30 ± 0.09 ABa	0.27 ± 0.02 ABa

Note: Capital letters indicate significant differences between different storage days at the same treatment and small letters indicate significantly different treatments at the same storage day.

Table 5: Resilience of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control (N)	0.50% Betel Leaves Extract (N)	1% Betel Leaves Extract (N)	2% Betel Leaves Extract (N)	1.25% SMS (N)
0	0.38 ± 0.10 Aa	0.39 ± 0.05 Aa	0.42 ± 0.04 Aa	0.58 ± 0.06 Aa	0.40 ± 0.11 Aa
4	0.33 ± 0.01 Aa	0.38 ± 0.02 Aa	0.41 ± 0.05 Aa	0.44 ± 0.06 Ba	0.47 ± 0.01 ABa
8	0.56 ± 0.05 Ba	0.42 ± 0.02 Aa	0.43 ± 0.02 Aa	0.49 ± 0.03 Ba	0.48 ± 0.08 ABa
12	0.42 ± 0.11 Aa	0.40 ± 0.04 Aa	0.43 ± 0.02 Aa	0.46 ± 0.03 Ba	0.53 ± 0.13 Ba
16	0.45 ± 0.06 ABa	0.46 ± 0.09 Aa	0.49 ± 0.10 Aa	0.53 ± 0.11 ABa	0.46 ± 0.05 ABa

Note: Capital letters indicate significant differences between different storage days at the same treatment and small letters indicate significantly different treatments at the same storage day.

the value showed a significant decreasing trend ($p < 0.05$) with prolonged storage. In contrast, *P. vannamei* coated with 1.25% SMS showed an increasing resilience value with prolonged storage, up to 12 days. This indicates that *P. vannamei* meat underwent some internal structural changes during storage. Some studies state that temperature might have the potential to affect the myofibrillar protein to bring about immediate to intense contractions of muscle of the *P. vannamei* meat (Okpala, 2015). Resilience in *P. vannamei* texture is important in food processing because it can affect the final texture of the product. A more resilient *P. vannamei* can be more easily cut and processed and can maintain its shape during the processing process. *P. vannamei* that has rotted or is not fresh generally have low resilience, as the meat has softened and cannot return to its original shape after being stressed.

Colour Analysis of Panaeus vannamei

P. vannamei coated with 2.0% betel leaf extract showed a significantly lower ($p < 0.05$) L* value throughout 16 days of storage compared to the controls. A similar result was found with regard to the *P. vannamei* coated with 0.5% betel leaf extract. However, L* value of *P. vannamei* coated with a 1.25% SMS showed a significant ($p < 0.05$) higher L* value compared to others at 16 days of storage (Table 6). The colour of *P. vannamei* was observed from light pink to deep red. A higher L* value indicates a lighter shade of pink, while a lower L* value indicates a darker shade of pink or red.

Initially, a* value of control was significantly lower ($p<0.05$) compared *P. vannamei* coated with 2.0% betel leaf extract. However, after being stored for 16 days in chilled storage, the a* value of control showed a significantly higher ($p<0.05$) value compared to the 0 day. In

Table 6: Lightness of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control	0.50% Betel Leaves Extract	1% Betel Leaves Extract	2% Betel Leaves Extract	1.25% SMS
0	36.15 ± 0.60^{aAB}	37.63 ± 0.29^{aA}	36.93 ± 0.55^{aAB}	35.95 ± 0.12^{aB}	36.94 ± 0.59^{aAB}
4	37.85 ± 3.14^{bA}	37.35 ± 0.79^{aA}	38.24 ± 1.51^{aA}	31.08 ± 0.65^{bB}	29.10 ± 0.45^{cB}
8	30.24 ± 0.32^{cA}	29.81 ± 0.38^{bA}	32.28 ± 2.22^{bB}	24.50 ± 1.57^{dC}	34.33 ± 1.49^{bD}
12	34.37 ± 0.73^{dA}	31.31 ± 0.15^{bB}	26.43 ± 0.37^{dC}	30.56 ± 0.58^{bcB}	33.37 ± 0.39^{bA}
16	32.01 ± 0.12^{cA}	31.30 ± 0.42^{bAB}	29.90 ± 0.09^{dBC}	29.23 ± 0.14^{cC}	34.98 ± 0.44^{bD}

Note: Capital letters indicate significant differences between different storage days at the same treatment and small letters indicate significantly different treatments at the same storage day.

Table 7: a* value of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control	0.50% Betel Leaves Extract	1% Betel Leaves Extract	2% Betel Leaves Extract	1.25% SMS
0	0.16 ± 0.08^{aA}	0.93 ± 0.15^{aB}	0.44 ± 0.25^{aA}	0.90 ± 0.02^{aBC}	0.47 ± 0.15^{bAC}
4	2.22 ± 0.78^{bA}	2.01 ± 0.39^{bAB}	0.52 ± 0.16^{aC}	0.12 ± 0.25^{bC}	1.58 ± 0.05^{aB}
8	1.24 ± 0.34^{cAB}	0.54 ± 0.15^{aBC}	1.49 ± 0.40^{bA}	1.603 ± 0.17^{cA}	0.85 ± 0.04^{bBC}
12	0.71 ± 0.16^{dAC}	2.63 ± 0.27^{cB}	0.49 ± 0.10^{aA}	1.12 ± 0.25^{aC}	0.40 ± 0.05^{bA}
16	0.59 ± 0.09^{eA}	1.50 ± 0.19^{dB}	0.79 ± 0.17^{aC}	0.37 ± 0.25^{bCD}	0.11 ± 0.51^{cD}

Note: Capital letters indicate significant differences between different storage days at the same treatment and small letters indicate significantly different treatments at the same storage day.

contrast, a* value of *P. vannamei* coated with 2.0% betel leaf extract showed a significant decrease ($p<0.05$) value after 16 days of storage. The least a* value was found in *P. vannamei* coated with 1.25% SMS at the end of the storage day (Table 7). A positive a* value indicates that the colour of *P. vannamei* has more red tones and a negative value indicates that the colour has more green tones.

The b* value of control at 0 day of storage showed a significantly lower ($p<0.05$) value compared to *P. vannamei* coated with SMS. However, the b* value showed no significant difference ($p > 0.05$) in *P. vannamei* coated with 2.0% betel leaf extract. The b* value showed a significantly higher ($p < 0.05$) value in *P. vannamei* coated with 2.0% betel leaves extract at day 16th of storage compared to 0 day of storage. A similar result was found in regards to *P. vannamei* coated with 1.25% SMS (Table 8). A positive b* value indicates that the colour of the *P. vannamei* has more yellow tones and a negative value indicates that the colour has more blue tones.

In general, the colour of the *P. vannamei* tends to turn dark due to melanosis, this is due to the polyphenol oxidase (PPO) enzyme biochemical reaction. PPO is certainly not harmful to humans. PPO enzyme oxidises phenols (colourless) to quinones (coloured), to form melanin (Illera *et al*., 2019). In addition, based on other studies, the higher the concentration of betel leaves, the darker the colour will be, a* and b* values also increased after the application of the betel leaves extract (Hoppy *et al*., 2018). The colour changes were observed where the L* value of *P. vannamei* decreased in value but remained positive and indicating that the colour of *P. vannamei* is becoming darker while still retaining its basic hue.

Additionally, the a* value indicates that the colour of the *P. vannamei* is becoming redder until day 8 but showed a decreased value at the end of the experiment. The b* value indicates that the colour of the *P. vannamei* is becoming more yellow until day 8, but becomes less yellowish at the end of the experiment. Furthermore, decomposed shrimp will release volatile amine compounds during storage, causing the anthocyanin structure to change to its basic form, resulting in colour change (from pink to greenish colour) (Suratsawadee *et al*., 2022) as observed at the end of the experiment.

Sensory Analysis

The quality of the *P. vannamei* coated with 0, 0.5, 1.0 and 2.0% betel leaves extract and 1.25% SMS showed that the quality of *P. vannamei* declined from the initial day to day 16 of storage. The characteristics used to describe the *P. vannamei* are based on grading criteria for the sensory test set in Table 1. On the 4th day of storage, *P. vannamei* coated with 2.0% betel leaf extract and 1.25% SMS showed good colour compared to other treatments, which showed

Table 8: b* value of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage

Storage Time (days)	Control	0.50% Betel Leaves Extract	1% Betel Leaves Extract	2% Betel Leaves Extract	1.25% SMS
0	0.45 ± 0.14aA	1.19 ± 0.06aB	0.09 ± 0.10aA	0.15 ± 0.04aA	0.56 ± 0.18bC
4	5.45 ± 0.50dA	3.07 ± 0.60bB	1.55 ± 0.49bC	1.07 ± 0.32bC	3.68 ± 0.47dD
8	3.47 ± 0.25cA	3.15 ± 0.09bA	5.24 ± 0.24cB	4.35 ± 0.54dC	4.69 ± 0.17eBC
12	3.76 ± 0.38cA	7.55 ± 0.40cB	3.91 ± 0.08dA	1.76 ± 0.18cC	0.49 ± 0.08aD
16	1.54 ± 0.16bA	2.3 ± 0.09d B	1.18 ± 0.02bA	5.12 ± 0.37eC	1.56 ± 0.07cA

Note: Capital letters indicate significant differences between different storage days at the same treatment and small letters indicate significantly different treatments at the same storage day.

natural light pink to white (Figure 1). The other treatments showed a moderate colour that was natural light pink with a grey-greenish hue. On the last day of the experiment, *P. vannamei* coated with 2.0% betel leaves extract, 1.0% betel leaves extract and 1.25% SMS showed natural light pink with yellowish discolouration. Meanwhile, other treatments showed a lack of defined colour. During storage, the colour of the shrimp deteriorated, indicating the occurrence of lipid and phenol oxidation (Li *et al.*, 2020).

P. vannamei texture was not significantly ($p > 0.05$) changed during the first 4 days of storage, where the body had a defined shape and was firm (Figure 2). *P. vannamei* texture maintains a firm texture for up to 4 days of storage after harvesting (Nunak & Schleining, 2011). On the fifth day, the texture of *P. vannamei* showed a slight change, where the flesh had slight firmness, but the texture was in a defined shape. *P. vannamei* coated with 2.0% betel leaf extract and 1.25% SMS showed a slower process of quality texture deterioration compared to other treatments. On the last day of the experiment, the texture of *P. vannamei* coated with 2.0% betel leaves extract and 1.25% SMS showed an easily pushed with a finger but was not pliable, compared to other treatments where the meat was soft and pliable. Chemical and biological reaction in shrimp, even in frozen temperature, including oxidative changes of lipids and protein in the muscle causes the quality of shrimp texture to deteriorate (Valencia-Perez *et al.*, 2015).

Spoilage *P. vannamei* emits unpleasant odours. On the second day, *P. vannamei* odour was diminished, with a weak fishy odour, and a slight ammonia smell could be detected in all treatment samples (Figure 3). However, *P. vannamei* coated with 2.0% betel leaf extract showed the slowest odour deterioration process

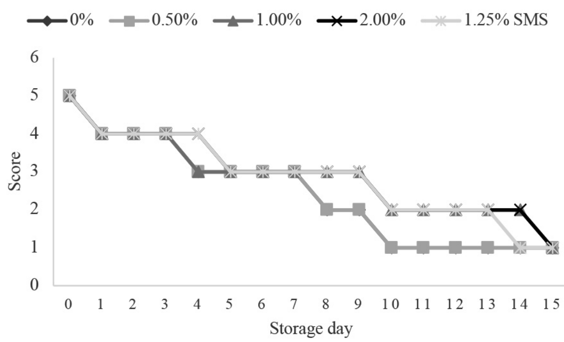

Figure 1: Colour quality of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage based on sensory test

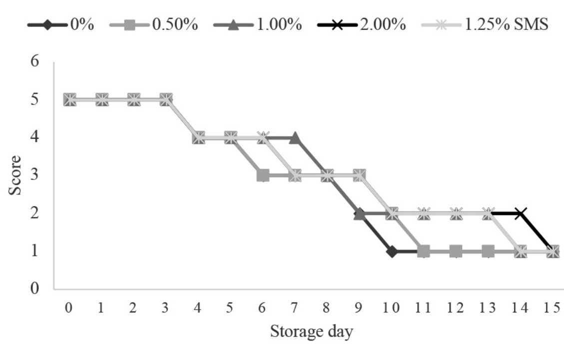

Figure 2: Texture quality of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage based on sensory test

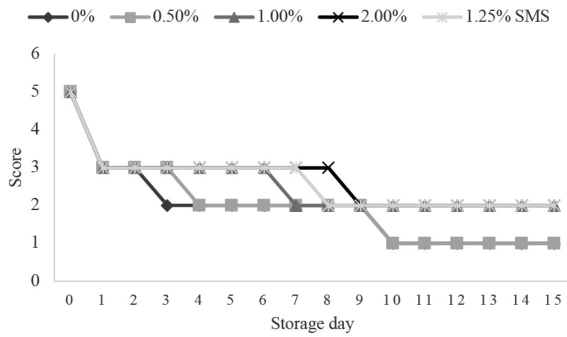

Figure 3: Odour quality of *P. vannamei* coated at different concentrations of betel leaves extract and 1.25% SMS in 16 days of chilled storage based on sensory test

compared to other treatments. On the last day of storage, *P. vannamei* coated with 2.0% and 1.0% betel leaves extract and 1.25% SMS emitted a slight odour of ammonia compared to other treatments. The emission is a strong ammonia odour. Bacterial contamination and enzymatic activity on shrimp during the storage process cause protein, fat and carbohydrates to decompose into ammonia, hydrogen sulphite, ethyl mercaptan, aldehydes, aldehydes acids, alcohol, ketones, and carboxylic acid gas cause of unpleasant odour (Du *et al.*, 2015).

One possible compound in betel leaves that have biological properties in *P. vannamei* is eugenol. Eugenol is a phenolic compound found in betel leaves (Hadzir & Hadzuin, 2012). Eugenol has been shown to have antimicrobial activity against various foodborne pathogens. When applied to *P. vannamei*, it may reduce the bacterial load on the surface of the shrimp, which can improve their shelf life (Marchese *et al.*, 2017). Eugenol can interact with proteins in the *P. vannamei* tissue, causing changes in their physical and chemical properties. For example, it may alter the surface charge or hydrophobicity of the *P. vannamei* proteins, which could affect their solubility, stability, and functionality. Eugenol could also affect the lipid content and composition of shrimp, which may lead to changes in texture, flavour, and aroma. Eugenol also could potentially interact with the pigments in the shrimp, resulting in changes in their colour (Aara *et al.*, 2020).

P. vannamei colour, texture and odour can influence consumer acceptance. Consumers prefer *P.vannamei* with natural and translucent colours ranging from greyish to light pink. Brightly coloured or unnatural-looking *P. vannamei* may be perceived as less desirable. Furthermore, *P.vannamei* texture should be firm and tender and the odour of *P. vannamei* should have a mild and salty smell. The use of 2.0% betel leaves extract gives the best score in prolonging the shelf life of *P. vannamei* comparable to SMS and other treatments until the 10th day of the experiment. While on the 11th day of the experiment, all treatments showed that the *P. vannamei* are unacceptable for the consumer.

Conclusion

The texture attributes of *P. vannamei*, along with body colour and sensory evaluation, provide comprehensive information about *P. vannamei* quality. By considering these factors, consumers can assess the freshness, taste, and overall desirability of *P. vannamei* they are consuming. This study suggested that coating *P. vannamei* with 2.0% betel leaf extract can help maintain the quality during chilled storage for up to 16 days. The coating resulted in a decrease in hardness, springiness, cohesiveness, and resilience, which indicates that the texture of the *P. vannamei* became firmer and less cohesive and resilient with prolonged storage. However, *P. vannamei* coated with 2.0% betel leaf extract had significantly different colour values (Lowest L* value and a* and highest b* value) compared to other treatments throughout the storage day. *P. vannamei* were preferred to have a higher L* value, lower a* value and lower b* value within the acceptable range for shrimp's characteristic pinkish or reddish colour. The sensory evaluation showed that the *P. vannamei* coated with 2.0% betel leaf extract was highly accepted by the consumers. Therefore, the results suggested that coating *P. vannamei* with 2.0% betel leaf extract is a promising approach to maintaining the quality of the shrimp during commercialisation and prolonging its shelf-life.

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